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DESCRIPTION OF THE SYSTEMS DESIGN LABORATORY
DISPLAY CONSOLES

TECHNICAL DOCUMENTARY REPORT NO.   ESD-TDR-64-150

FEBRUARY 1965

J. Mitchell

Prepared for

DEPUTY FOR ENGINEERING AND TECHNOLOGY

ELECTRONIC SYSTEMS DIVISION

AIR FORCE SYSTEMS COMMAND

UNITED STATES AIR FORCE

L. G. Hanscom Field, Bedford, Massachusetts

Project 250.0
Prepared by

THE MITRE CORPORATION
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ABSTRACT

Six display consoles have been purchased for the Systems Design Laboratory (SDL) to facilitate rapid, accurate communications between the SDL data processing facilities and the display operators. These consoles may be connected to any computer able to control IBM 729 series magnetic tape drives. Each console contains a 2048-word magnetic core memory for storing display data which is coded in a highly efficient manner. It also contains display storage in the form of a 64-frame film strip any frame of which may be presented on the display. Display generation is very rapid and is capable of showing alphanumeric and special characters, straight lines, and points. The appearance of a number of the special characters is under control of the data processor's program. The display operator is provided with switches, a light pencil, and a typewriter able to generate inquiries or statements for entry into the data processor's program.

REVIEW AND APPROVAL

This technical documentary report has been reviewed and is approved.

WILLIAM L. MARTIN
Major, USAF
Technical Support Office
Deputy for Engineering and Technology

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INTRODUCTION

The Systems Design Laboratory has been assembled to permit Command
and Control System designs to be evaluated. The majority of the experiments
to be conducted require fast, accurate communication between men and a data
processor. A display system which can interpret data from the computer,
present it graphically, and simultaneously provide the viewer with a means of
communicating with the computer was required since many different tasks will be
simulated requiring a variety of display characteristics.

Such displays were specified by MITRE, and were purchased to this
specification from Data Display, Inc., St. Paul, Minnesota.

The displays described in this report are designed to accept digital data
from a computer through an interface identical to that used to operate IBM 729
series magnetic tape drives. The digital data is stored in a 2048-word magnetic
core memory. The display reads the data from its memory, interprets it, and
presents information in the form of bright lines on a CRT. These lines are
arranged by display to represent alphanumeric characters, vectors or points
according to the data provided by the computer.

Branch switches permit the viewer to select the data to be displayed.

The display viewer may enter data into the computer; a section of the
display memory is reserved for the temporary storage of such data before it is
transmitted to the computer. This data may be generated through use of light
pencil, switches or typewriter keyboard.

The display is equipped with a graphic display subsystem consisting of a
flying spot scanner which raster scans a computer-selected film transparency.

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Thus, a television-like picture of the image on the film transparency is built up on the display. The display tube may be time-shared between graphic and symbolic displays so that the two display images are apparently superimposed.

SECTION II

PHYSICAL DESCRIPTION

This display system has two major components; the console which contains
the display surface proper and the logic cabinet containing the digital circuits
to generate and control the display. Figure 1 is a photograph of the two units
together although in operation they may be separated up to 80 feet.

DISPLAY CONSOLE

The display console is 45 inches high, 33. 5 inches wide and 51 inches
deep not including the 14. 5-inch shelf in front of the display surface. (The low
height permits a seated operator to view a wall display over the top of the
console.) It contains the CRT, the power supplies, deflection and unblanking
(intensifying) amplifiers for the CRT, the graphic display subsystem and the
light pencil subsystem. Its weight is approximately 500 pounds. The console
is grey with a blue top and dark grey matte finish front panel and work shelf.

Display Surface

Four of the six consoles contain 19-inch diameter CRT's; the other two use
16-inch CRT's. All CRT's use electrostatic deflection systems to permit high
writing rates. The 19-inch CRT faceplates have a radius of curvature of 33
inches while the 16-inch CRT's have faceplates with a radius of curvature of
56 inches. The plane of the front panel of the console is tilted 100° away from
the horizontal work shelf between display and operator. Between faceplate and
observer is a special implosion shield which contains a circular polarizer
between two sheets of plate glass. The viewing side of the screen is coated
with High Efficiency Anti-reflectant coating applied by the Optical Coating
Laboratory of California.

3
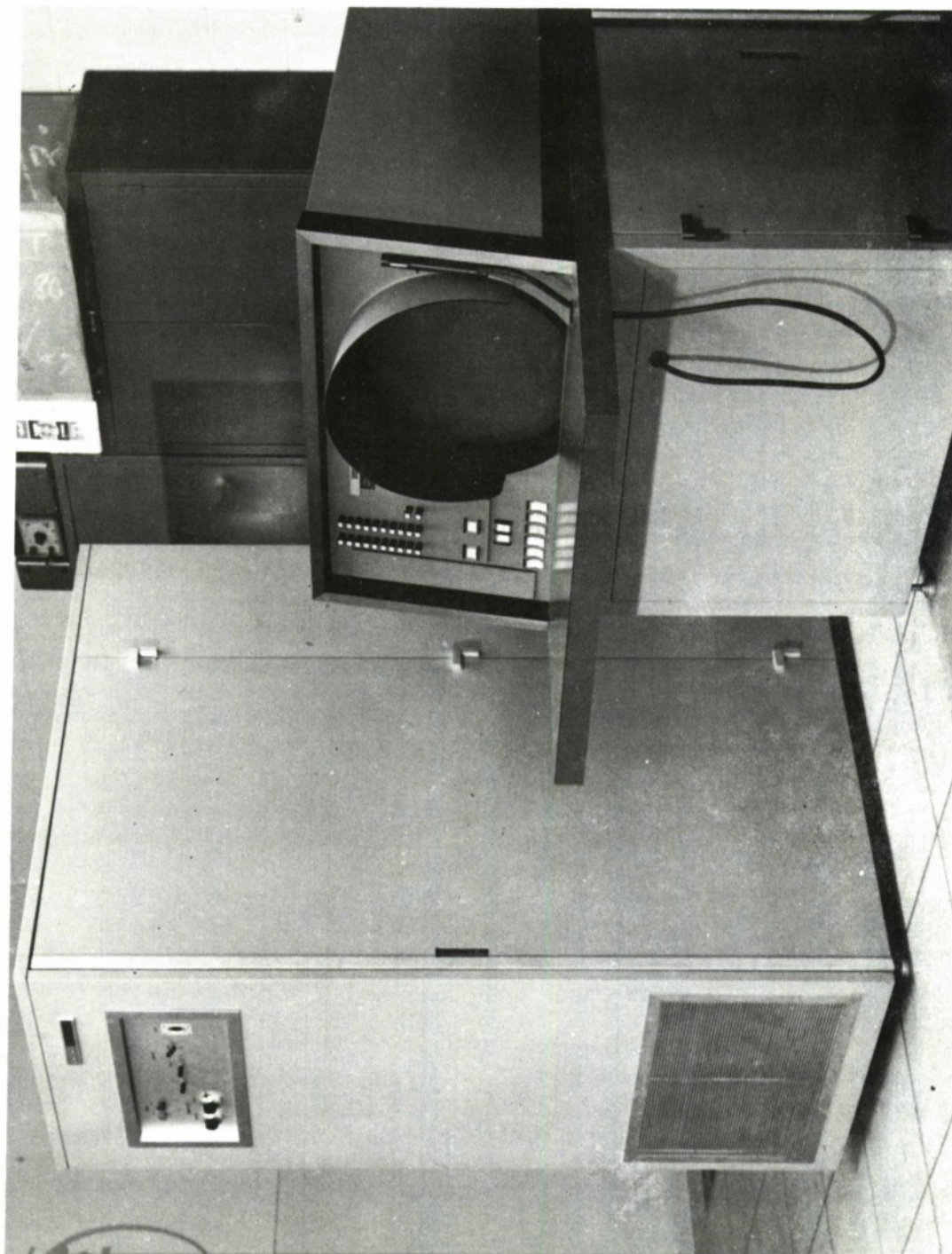
Fig. 1. Systems Design Laboratory Display System

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The phosphor used in the CRT's is P-31, a high-efficiency, green phosphor of fairly short persistence.

Control Panel

The control panel, Fig. 2, in which the display surface is mounted is 31 inches wide and 16.25 inches high. There are three main sets of controls on this panel: those required to adjust the clarity and brightness of the display, those required for the generation of input data, and those required for the selection of data from the display memory.

Display Adjustments

A hinged cover at the left of the control panel conceals controls required for adjusting the intensity, focus and astigmatism of the display and flying spot scanner. There is also a control to adjust the relative brightness of graphic and symbolic displays.

Data Entry Switches

Twenty-two pushbuttons are at the upper left of the front panel. The switches are identified by numbers 1 through 22. (In a particular application they may be differently labelled.) These pushbuttons latch when depressed and any number can be operated at one time. Operation of the large pushbutton below the leftmost column unlatches all depressed switches; operation of the large pushbutton below the righthand column generates the input message and loads it in the display memory; it also releases the depressed switches.

Light Pencil

A light pencil (a pencil shaped device for detecting photoelectrically the flash of a displayed item) is mounted on a holder to the right of the display surface. The "cable" attached to this light pencil and running down through the shelf conducts the light flash to a photomultiplier tube inside the console.

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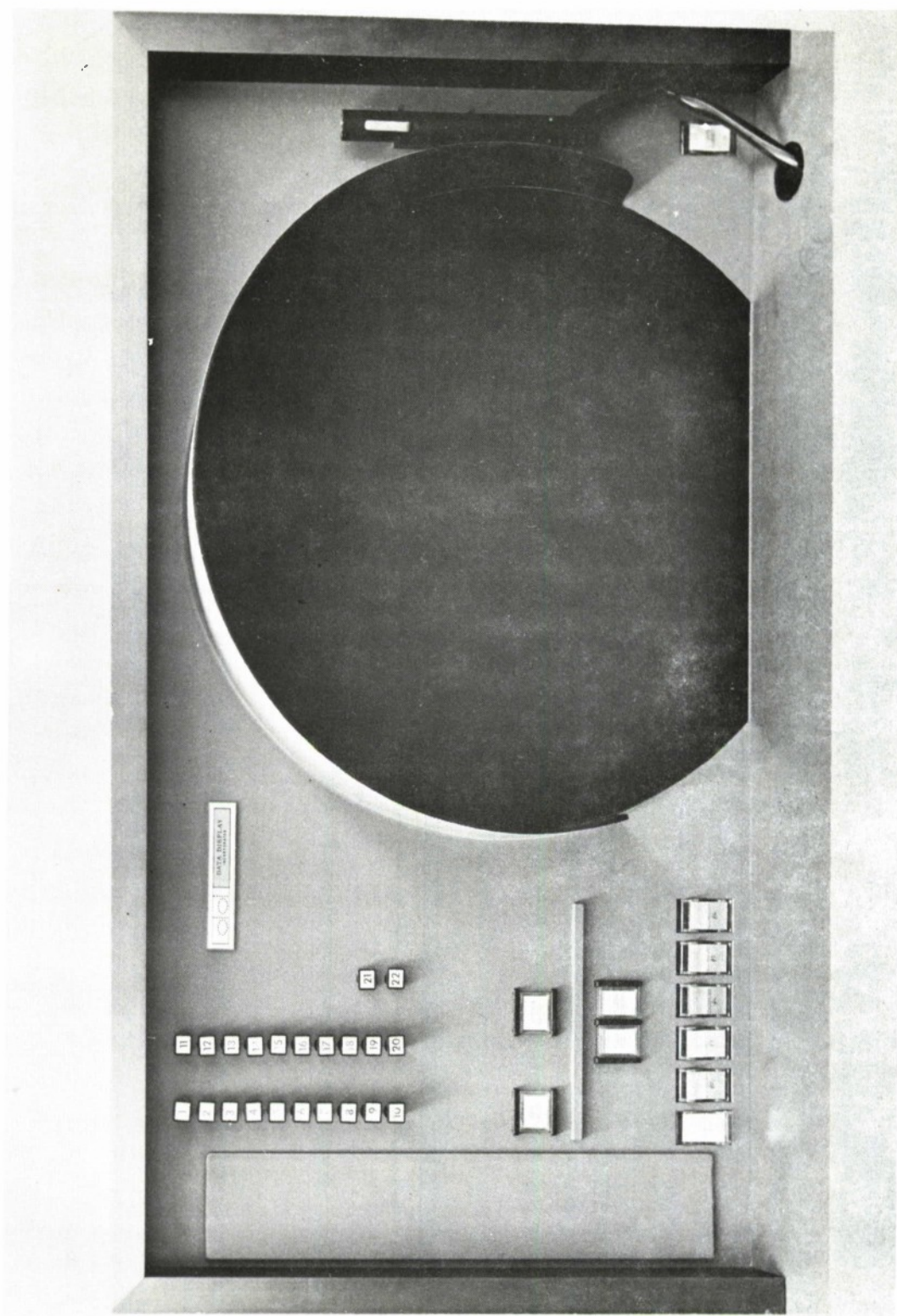
Fig. 2. Display Console Front Panel

The light pencil is provided with a switch that can be operated by radial pressure of thumb or forefinger. Light pressure causes a perceptible switch closure which turns on lights in the pencil to project an aiming circle in front of it. With the pencil held about 2 inches from the display surface the aiming circle is a focussed ring of lights about 0.2 inch in diameter. Displayed items within that ring are detectable by the light pencil. At other distances the aiming circle is unfocussed but the light pencil is still able to detect displayed items. Further pressure on the switch results in a second perceptible switch closure. This closure has the effect of enabling the light pencil detection; it is only after this second switch closure that the detection of a flash can be logically recognized by the display. When the light pencil logic detects a display, the aiming circle starts to flash at a rate of about 5 cycles per second.

Branch Switches

Six 3-position, center-off, butterfly switches are mounted in a row at the left of the front panel just above the shelf. They are used for selecting data from the display memory to be displayed.

Console Manned Switch

A three-position, butterfly switch is mounted at the lower right of the front panel. It indicates to the computer that the console is manned and ready to receive data.

Miscellaneous Switches

Two other switches are provided just below the data entry switches. These are both large pushbuttons. The left switch is labelled CLEAR BELL and is used to turn off the console bell. The right switch is labelled ILLEGAL ENTRY and may be used to turn off the ILLEGAL ENTRY light which is an integral part of the pushbutton.

Bell

The console is provided with a bell which sounds a pair of notes about
0.5 second apart. The bell can be rung only under computer control either
once or indefinitely at 5 second intervals. If rung for an indefinite period it
must be turned off manually at the console.

Display Size and Position Controls

Within the display console a panel of eight controls is provided for
adjusting the size and position of both the symbolic and graphic images on the
display surface.

LOGIC CABINET

The logic cabinet is 68 inches high, 28 inches wide and 48 inches deep.
It weighs about 1100 pounds. Three-foot-wide doors at each side open to allow
printed circuit card racks to swing out for maintenance. Within one door is a
small maintenance control panel which permits manual operation of the display.
A few operating controls are mounted at one end of the cabinet; at the other end
a door opens to reveal the cabling between circuit card racks, and the connection
for cables to the display console and the Tape Adapter Unit (TAU).

The logic cabinet contains the core memory, and all the circuits for
transferring data to and from the computer, for interpreting data from the
memory, and for generating analog positioning and intensification voltages
for the console.

External Operating Controls

The operating controls which are mounted on the end of the logic cabinet
consist of the power on/off switches, character size controls, the selector
switch to identify the display to the TAU and three display mode switches.

Maintenance Controls and Indicators

The maintenance controls permit the display to be operated in manual mode (at normal speed or one word at a time), and to accept and store manually entered data.

The maintenance indicators permit the operator to read the logical state of the display register, the output register, the memory address register, and the mode-determining flip-flops.

SECTION III

DISPLAY CHARACTERISTICS

SYMBOLIC DISPLAY

Brightness

The brightness of the displayed symbols may be adjusted from visual extinction to over 300 foot-lamberts. This latter brightness was measured by displaying a raster of lines having a nominal width of 0.015 inch spaced about 0.010 inch apart and displayed at a repetition rate of 60 cps. The brightness was measured with a Spectra Brightness Spot Meter with the intensity control on the display turned up until marked halation appeared around the raster. A useful maximum brightness at which line widths are still well defined and there is no halation is about 100 foot-lamberts.

Alphanumeric Characters

The display is able to present 44 fixed alphanumeric and punctuation characters and 18 programmable characters whose appearance is determined by the computer program. The alphanumeric characters are shown in Fig. 3, a a photograph taken from the face of one of the displays. The nominal height of the smaller characters is 0.125 inch but the character size controls permit adjustments between less than 0.0625 inch and over 0.20 inch. The nominal character width is 3/4 of the character height but since width can be adjusted independently of height any ratio may be set. The 3 to 4 width to height ratio has been chosen for good legibility. The stroke width of the characters is between 0.010 inch and 0.020 inch. Characters may also be displayed twice normal size under program control.
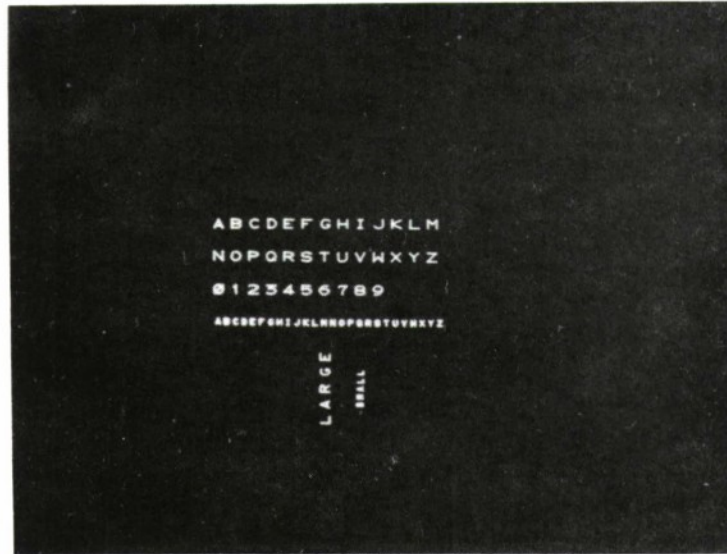
Fig. 3. Character Display

Programmable Characters

The appearance of each of the 18 programmable characters is stored in four memory words in the display. Decoding the code identifying a programmable character refers the character generator to these memory locations. The overall size of these characters is the same as for the alphanumeric characters. The appearance of these characters may be made to correspond to that of the alphanumeric characters with the restriction that the more complex alphanumeric characters cannot be displayed with only one programmable character.

Programmable character codes may require the character to be overprinted on the previous character and/or to be displaced slightly above or below the normal line of characters. Thus it is possible to use programmable characters for superscripts, subscripts, overlines, and underlines. The

detailed rules for the programming of these characters are presented in
an appendix to this report.

Vectors

Vectors are represented on the display surface by straight lines. Their
length may be anything from the least programmable increment (about 1/1000
of the display dimension) up to the full diagonal of the display. The maximum
excursion from a straight line path is less than 2 percent of the length of the
vector. The repeatability of the vectors, as of the other symbols, is such that
broadening of the lines is not observed.

Points

Points with a nominal diameter of 0.010 to 0.020 inch can be displayed
on the CRT surface.

Focus

Focus of the display is excellent. The display contains dynamic focus
circuits to vary the focussing voltage as a function of the position of the display.

Reflections

The implosion screen is designed to minimize reflections and provide a
very high contrast display. With a horizontal light component of 22 foot-
candles at the center of the screen, reflected brightness was 1.7 foot-lamberts.
A 20 foot-lambert symbol is exceptionally easy to see. The only reflection
readily visible is a very dim image of the observer.

Positioning

The positions of displayed points, of the centers of characters, and of
the starting points of vectors are controlled by X and Y 10-bit registers.

Increasing values of X and Y represent positions moving towards the right and top of the display surface respectively. Normally the gain and positioning controls will be adjusted so as to place the origin of the coordinate system in the lower left corner 0.5 to 1 inch from the edge of the CRT faceplate. Full scale deflection (X and Y registers both at their maximum values) will position the electron beam an equal distance from the upper right edge of the CRT. The coordinate system thus covers an area about 12 inches square on the 19-inch CRT's and about 10.5 inches square on the 16-inch CRT's.

Under program control it is possible to create displays in the right, left and upper marginal areas of the CRT between the edge of the round faceplate and the borders of the square coordinate area. A temporary displacement of the origin of the coordinate system, by one-quarter of full scale, is used to achieve these displays. The lower marginal area of the CRT is not used in this manner as it lies below the level of the work shelf in order to reduce the height of the console.

GRAPHIC DISPLAY

The graphic display is produced by a 1024-line raster consisting of two, 512-line, interlaced fields presented alternately. Graphic display fields are alternated with symbolic displays at maximum intervals of 1/120 second. The first graphic display field (1/120 second) is followed by one complete symbolic display cycle or 1/120 second of symbolic display, whichever is shorter. Then the second graphic field is shown followed by a further 1/120 second of symbolic display starting from the program location where it stopped during the previous interval.

Brightness

The brightness available from the graphic display is, for all practical purposes, the same as that available from the symbolic display. It can be

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adjusted relative to that of the symbolic display. The range of adjustment is sufficient to give a clear visual impression that bright symbols are overprinted on a dimmer graphic display.

Contrast

With the graphic display adjusted for the best resolution and requiring 1/120 second for each 512-line field, the contrast obtainable is good, though not as good as that of the symbolic display. The gain-bandwidth in the scanner photomultiplier amplifier does not give enough signal to drive the display CRT between cutoff and full brightness. By reducing the scanner sweep rate, both improved resolution and improved contrast can be obtained with a loss of the time available for symbolic display. By increasing the gain of the amplifier following the photomultiplier, greater contrast is available but resolution (which requires wide bandwidth) suffers. Efforts are being made to improve the graphic display contrast without loss of resolution.

Resolution

The resolution of the graphic display is between 500 and 600 lines horizontally and vertically. The resolution was measured by displacing a standard resolution chart and determining by eye the resolution number at which the lines were no longer distinguishable. As previously mentioned, this resolution, at least horizontally, is limited by the bandwidth of the scanner system. However, it is also limited by the size of the spot on the scanner CRT and the decay characteristics of the phosphor; higher resolution cannot be expected. It is anticipated that future developments will permit the same resolution to be obtained with a higher contrast picture.

Registration

The graphic and symbolic displays occupy the name space on the output CRT. The graphic display controls provide means for adjusting the registration for any one film. The linearity of the sweep systems is then sufficiently good that misregistrations are less than 1 percent of full scale. The registration was tested by using the graphic mode to display an array of squares uniformly spaced in both directions, each square being 2 percent of the film transparency dimension on each side. At the same time the symbolic display was used to show an array of points programmed to lie on the nominal centers of the squares. Adjustment of the graphic display controls permitted all points to be simultaneously displayed within the corresponding squares.

The film transport mechanism must also be accurate and repeatable so that every time it returns to a given film transparency the same good registration is obtained. A series of tests with the display described in the last paragraph was performed by changing film transparencies and then returning to the test transparency. Each time this was done the 1 percent registration held good.

Graphic Display Films

The graphic display system contains a film strip of sixty-four 35-mm transparencies. Which transparency will be displayed is under computer program control. Each transparency should be one-inch square if the data is to fill the display area although the gain controls can be used to effectively increase the size of a smaller image area (at reduced resolution). The longitudinal direction of the film strip corresponds to the vertical direction on the display. Between the center of successive transparencies there must be exactly 12 sprocket holes. A camera with the precise film transport

necessary is available at MITRE. It is fitted with a boresight tool so that the center of the image space can be aligned with the center of the image. For producing film strips, this camera will be mounted on an optical bench or equivalent and it should be possible to register the images with the sprocket holes to approximately 1 part in 500.

The graphic display film is required to stand fairly rough handling in the film transport. Dupont "Cronar" Ortho A (Order Code COA4) 35 mm with Fastax perforations is recommended. The leader should be about two feet long.

The flying spot scanner system gives a negative going signal out of the photomultiplier for increasing light passing through the film image. However, the polarity of the signal out of the amplifier may be chosen so that the display is intensified for either clear or dark areas on the film. Normally the system will be connected so that clear areas on the film produce dark areas on the display. The reason for this is that noise pulse signals out of the photomultiplier simulate light passing through the film; dark spots on a normally bright field are less annoying than bright flecks in a normally dark field. Therefore, negative film strips should be used. In other words if it is desired to produce bright symbols on a dark field one should photograph bright symbols on a dark field with negative film or dark symbols on a bright field with positive film. The choice of film depends on the data that is to be photographed.

SECTION IV

INTERFACE

PHYSICAL DESCRIPTION

The interface between the display consoles and an associated computer
is identical to that used with series 729 IBM magnetic tape drives. The timing
of the interface is set for 729 IV high-density data rates but can easily be
changed to other rates up to 300,000 characters per second. In addition to the
wires common to all 729 tape drives the consoles are each provided with a
+P Machine Ready line which is, presently, unique to the 7030 (STRETCH) tape
drives. The Machine Ready line provides the console with means of generating
an interrupt signal to the computer.

INTERRUPTS

Each console can generate a pulse on its Machine Ready line. This
serves as an interrupt signal in the SDL system. There is one Machine Ready
line to the 7613 Tape Control Unit from each console or tape drive. A 7613
TCU uses the signal on any one of its Machine Ready lines to signal the 7030 I/O
channel that one of its connected units has become ready. It does not normally
identify which unit has become ready. In the Systems Design Laboratory,
however, the consoles are connected to a modified 7613 containing a register
which stores the identification of the unit which caused the interrupt. It also
signals the channel that an interrupt has occurred. This special register is
identified to the computer as tape drive # 7. When the computer issues a Read
instruction to tape drive #7, it is this special register which is read and the
data obtained from it identifies the particular console or tape drive which
generated the interrupt. Subsequently the program can go directly to that

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console to read out the data whose generation caused the interrupt. Without this provision the computer would have to search each console until it came to the one, or ones, which had data for it.

When used with computers other than the 7030, the Machine Ready signal must be brought through an interrupt input appropriate to that computer.

TIMING

The rate of transfer of characters to and from the console is dependent upon the tape drives for which the TAU is designed. The rates available are 41,667; 62,500; and 90,000 characters per second when operated as a 729 II, IV, or VI, respectively. A simple change in the console adapts it to the desired rate.

There are a number of delays inherent in tape drive operations which are required to allow time for accelerating the magnetic tape. In the 7613 (modified) to which the display consoles are attached in SDL these delays have been greatly reduced. It requires only about 200 microseconds to start a transmission and another 100 microseconds to terminate it. Therefore the time required for the transfer of n characters is about $300 + 16n$ microseconds with a 729 IV TAU.

When used with unmodified TAU's, time is required to start and stop the tape. This time amounts to about 7 milliseconds with 729 IV and about 10 milliseconds with 729 II.

LOGICAL DESCRIPTION

Data Format

Data is transferred between the TAU and the console as a series of characters each consisting of six data bits plus an odd parity bit. On transfers to the console the characters are returned to the TAU as well as being stored

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in the console and are parity checked in the TAU; no parity checking is done in the console. On transfers from the console every character has the parity bit added before transmission. In addition the console generates the Longitudinal Redundancy Check Character, the last character sent during any transmission.

Commands

Data transfers are the only way in which the computer can control the display consoles. Therefore, the first character or characters in any transfer of data from computer to console are command characters which define console operations. The following sections list the commands which are available and the coding required. In each case characters over and above those required to specify the command or data are ignored by the display.

Load

The first character is coded 21_8 and requires that subsequent data be stored in the display memory. The second and third characters identify the address in the display memory in which the first four data characters are to be stored. The fourth and fifth characters identify the number of display console memory words (four characters each) which are to be stored. Succeeding characters comprise the data to be stored in the specified and higher numbered addresses. The computer may send a number of characters in excess of those required for storage; the display does not store or otherwise recognize these characters.

Transfer

The first character is coded 25_8 and requires the display to transfer data from its memory to the computer. The second and third characters identify the address in display memory from which the first four data characters are to be taken. The fourth and fifth characters identify the number of display

memory words to be transferred. Any following characters are ignored by the display. The actual transfer of data from the display starts when the computer puts the console into read status. If the computer attempts this read operation without first sending the Transfer command, the address from which transfers start is address 0000_8 and the number of words transferred is the number of words in the data entry storage. The first two characters transferred are always the word count; the identification of the number of words to be transferred.

Load a Typewriter Message

The first character is coded 22_8 and has the same effect as a load command. The data is intended for the typewriter and is not displayed. As in the load command, successive characters identify the address in which the first data characters are stored, the number of words to be stored, and the symbols to be printed.

Start Symbolic Display

The first character is coded 12_8 and requires that the display obtain a word from the memory location identified in the following two characters and interpret it as a display word.

Frame Selection

The first character is coded 35_8 and requires that the graphic display system select the film transparency identified in the next character. Characters in excess of these two are ignored.

Start Graphic Display

The first character is coded 11_8 and requires that the graphic display mode be started.

Start Graphic Display

The first character is coded 11_8 and requires that the graphic display mode be started.

Stop Symbolic Display

The first character is coded 16_8 and requires that the symbolic display mode be stopped.

Stop Graphic Display

The first character is coded 15_8 and requires that the graphic display mode be stopped.

Ring Once

The first character is coded 31_8 and requires that the display console bell give one pair of sounds.

Ring

The first character is coded 32_8 and requires the bell in the console to ring continuously until shut off manually.

SECTION V

DISPLAY GENERATOR PROGRAMMING

MEMORY

The memory contains 2048 twenty-four bit words. The memory cycle time is 6. 4 microseconds. The first 128 words (addresses 0000_8 through 0177_8) in memory are reserved for the storage of the operator's data entries. The next 72 words (address 0200_8 through 0307_8) are normally reserved for the storage of the descriptions of programmable characters. All other words in the memory are available for the storage of display data or messages for the typewriter.

DISPLAY MODES

Words stored in memory are interpreted by the display generator as instructions to display alphanumeric characters, lines, or points at specified locations. In order to permit efficient coding of the display data, the display generator has been designed to operate in a number of modes. The display generator determines which mode is required by examination of data obtained from memory; these mode-defining words are called display words. Words following the display words (words in successively higher numbered addresses) may be interpreted as display words or as data depending on the mode. Eight modes are available and are described in the following sections.

Raster Mode

The raster mode is used to present an array of 128 x 128 dots on the face of the CRT. Detection of a point by the light pencil may be used to identify a location on the CRT. The raster mode display word is coded as follows:

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Bit 0		Not specified
Bits 1- 3	000	Identifies the raster mode display word
Bits 4-23		Not specified

Display of a complete raster requires 55 milliseconds. However, since the purpose of the raster is to provide location reference points for the light pencil, the raster has been designed so that:

(1) It only starts when the light pencil switch is fully operated.

(2) It stops as soon as the light pencil detects a point in the raster mode.

(3) It cannot re-start until the light pencil switch has been released and reoperated.

Therefore, the time required for display of the raster depends on the location of interest; on the average it is 25 to 30 milliseconds. Figure 4 shows a complete raster display.

Point Mode

The point mode is used to display a single point at any location on the CRT. The point mode display word is coded as follows:

Bit 0		Not used
Bits 1- 3	001	Identify the point mode
Bits 4-13		Specify the X or horizontal position of the point on the face of the CRT with respect to the origin.
Bits 14-23		Specify the Y coordinate of the point position.
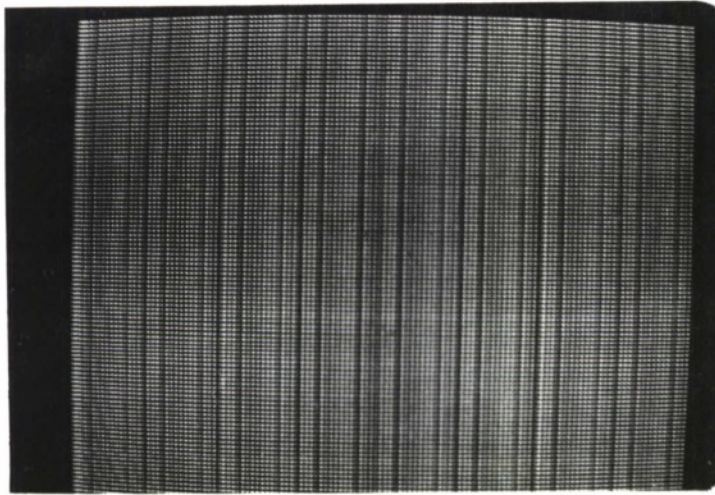
Fig. 4. Raster Display

The display of a point requires no more than the time required to obtain the data from memory (6.4 μs). Figure 5 shows a Point Mode display.

Character Mode

The character mode is used to display horizontal lines of characters. The display word is coded as follows:

Bit 0	0	Characters are written in their normal size, approximately 1/8-inch high.
	1	Characters are written in their larger size, twice normal.
Bits 1-3	010	Identify the character mode
Bits 4 -23		Specify the coordinates of the center of the first character.

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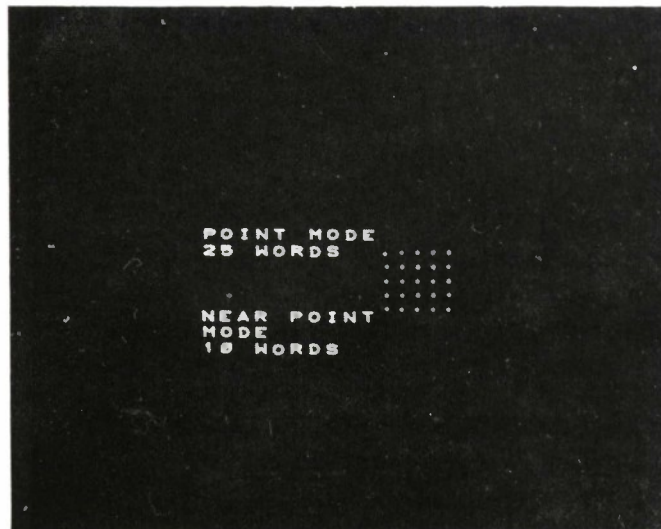
Fig. 5. Point and Near Point Display

Memory words following the display word are interpreted as specifying a series of characters to be displayed. Each word contains four 6-bit codes identifying 4 of the possible 63 characters (including the blank) or the END character. The distance between the centers of successive characters is 1/64 of the horizontal display dimension or 1/32 if large characters are being displayed. Should the resultant position be such that the character would lie beyond the bounds of the coordinate system, the character will appear at the left hand margin 1/64 of the display dimension (1/32 for large characters) below the line of characters that was being written, an effect similar to a carriage return action on a typewriter. All words following the display word

are interpreted in this manner until the END character is decoded. The memory word next following a word containing the END character is interpreted as a new display word specifying a new mode or a new position for continued writing in the character mode.

The six bits assigned to code each character permit the display of 62 characters and a blank; one code is reserved for the END character. The codes used are given in an appendix to this report. Forty-four of these codes are assigned to fixed alphanumeric and punctuation characters but 18 of the codes are used to identify programmable characters. These are characters whose descriptions are not wired into the display generator but are stored in memory locations 0200_8 through 0307_8. Thus the appearance of each of these characters may be programmed to appear 1/4-character height above or below the normal line and may also be programmed to overprint the last displayed character. The appendix gives the memory addresses corresponding to each programmable character code, and specifies the rules for coding these characters.

The time required to display a series of fixed characters is 8.6 microseconds each; the time required to display a series of programmable characters is 30 microseconds each. Figure 3 shows a character mode display.

Vector Mode

The vector mode is used to display a single straight line from the present position (as defined by previous display modes) with specified X and Y increments. Vectors may be any length up to a full display diagonal.

Bit 0	0	Vector is displayed normally
	1	Vector is displayed dashed
Bits 1- 3	011	Identify the vector mode display word

Bits 4-23   Specify the X and Y coordinate
                                             increments.   The first bit of each
                                             10 bit group is a sign bit - 0 (positive)
                                             represents rightwards or upwards
                                             directed vectors.   The remaining nine
                                             bits represent the X and Y increments
                                             coded in 10 bits each with the tenth
                                             bit assumed equal to the sign bit.
                                             ONE's complement coding is used.

A maximum of 30 microseconds is required to write a vector.   Vectors
shorter than 3 inches require 15 microseconds.   Those shorter than 0.75 inch
require about 9 microseconds and those shorter than 0.2 inch need less than
5 microseconds.   Figure 6 shows a vector display.
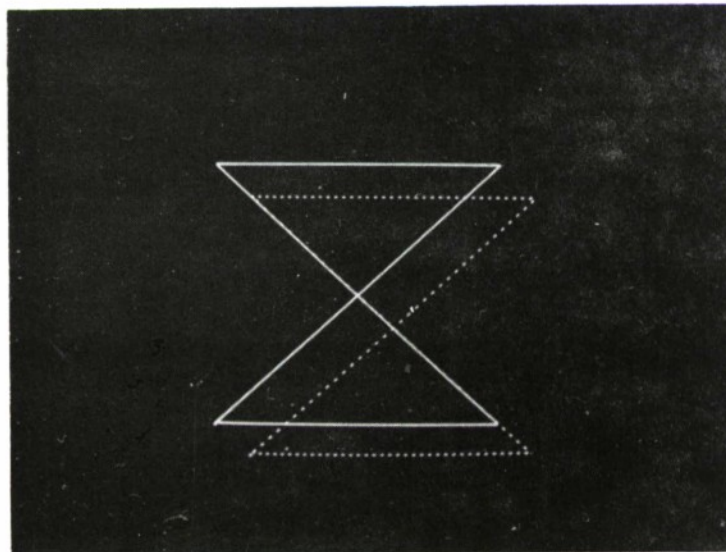
Fig. 6.   Vector Display

Short Vector Mode

The short vector mode is used to display a connected series of short straight lines. The display word is coded as follows:

Bit 0	0	Vectors are displayed normally
	1	Vectors are displayed dashed
Bits 1 - 3	100	Identify the short vector display word
Bits 4 - 23		Specify the location of the starting point of the first vector.

Memory words following the short vector display word are interpreted as three short vectors coded in eight bits each. Each group of eight bits contains two 4-bit groups specifying the X and Y coordinate increments between beginning and end of the vector. The first bit of each 4-bit group is the sign bit coded as for the vector mode. The remaining three bits are the three most significant bits of the 5-bit increment; the two least significant bits are assumed equal to the sign bit. Thus, assuming the 12-inch square display area on the 19-inch CRT's, the short vectors may be from 0.05- to 0.34-inch long (each component). The display times for short vectors are the same as for similar length vectors.

The interpretation of memory words as short vectors continues until a null vector is decoded (all eight bits are zero). A null vector is a command to interpret the next word from memory as a new display word. Figure 7 shows a short vector display.
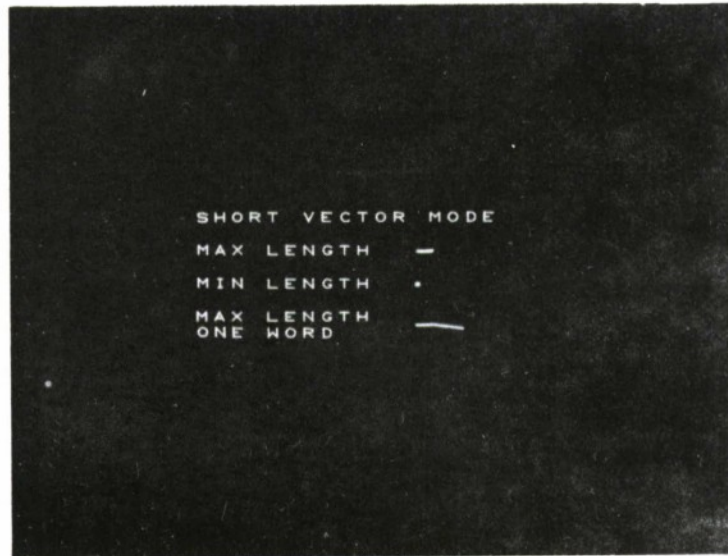
Fig. 7. Short Vector Display

Near Point Mode

The near point mode is used to draw a series of close-spaced points.
The display word is coded as follows:

Bit 0	0	Not used
Bits 1 - 3	101	Identify the near point mode
Bits 4 - 23		Specify the location of the first displayed point.

Memory words following the display word are interpreted as three 8-bit
groups each specifying the X and Y coordinate increments between successive
points. The coding of these increments is identical with the coding used for
the short vectors. In fact, a series of near points, starting at the same

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location and having the same incremental coding as a series of short vectors will be displayed precisely at the ends of the short vectors.

A pair of null increments is interpreted as a command to leave the near point mode.

The display of near points requires an average of 8 microseconds per point.

Near Character Mode

The near character mode is used to display a series of characters which are grouped but not necessarily in a horizontal line. The display word is coded as follows:

Bit 0	0	Characters are displayed in their normal size.
	1	Characters are displayed twice normal size.
Bits 1 - 3	110	Identify the near character display word
Bits 4 - 23		Specify the location of the center of the first character.

Memory words following the display word are interpreted as specifying successive characters to be displayed and the increments between these characters. They are coded in four 6-bit groups. The first and third groups specify the characters to be displayed; the second and fourth groups specify the X and Y coordinate increments to the next character. The increment groups are coded as two 3-bit groups with the first bit of each group being the sign bit and the next two being the two most significant bits of the 6-bit coordinate increment (a 7-bit increment if large characters are being

displayed). The four (or five) least significant bits are assumed equal to the sign bit. This coding permits successive small characters to be 1/64, 1/32, 3/64 of the respective display dimension from the last character in any direction. The END character requires that the next memory word be interpreted as a new display word.

Note that in the near character mode, the backspace coding of programmable characters is invalid because there is no automatic character advance to be over-ridden. However, overprinting can be obtained by encoding a null increment between characters.

The average time for the display of characters in the near character mode is about 12 microseconds. Figure 8 shows a near character display.
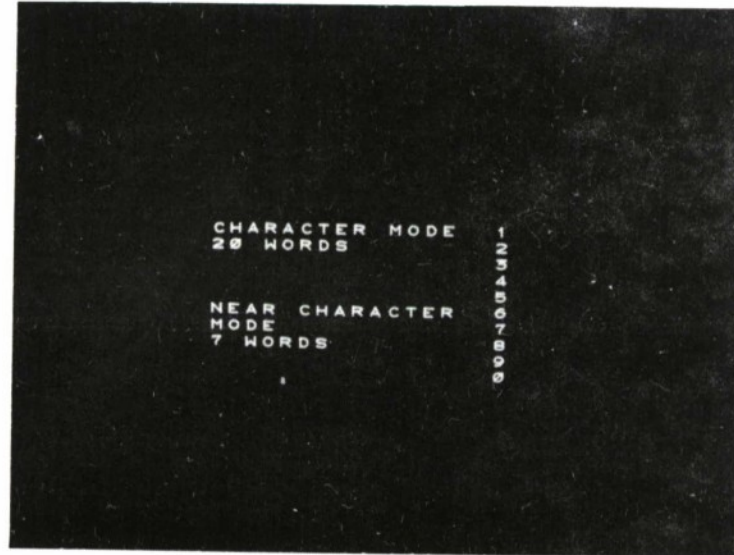
Fig. 8. Near Character Mode Display

Branch Mode

The branch mode allows the operator to control the display program by accepting the data following the branch into the display generator or branching to a different area of memory. The branch word is coded as follows:

Bit 0	0	The lower position of the branch switches determines the branch effectiveness.
	1	The upper position of the branch switches determines the branch effectiveness.
Bits 1 - 3	111	Identify the branch word
Bits 4 - 9		Are compared, in order, with the branch switches reading from left to right. If any bit is set to a logical ONE and the corresponding branch switch is operated (upwards or downwards depending on whether bit 0 is 1 or 0 respectively) then the branch is termed effective, the next display word is obtained from the next higher numbered address. Otherwise the next display word is obtained from the memory address given in bits 13 - 23.
Bit 10	0	Symbols are displayed at a fixed level of brightness (adjustable with the intensity control).
	1	Symbols are displayed at a level of intensity approximately twice that required when this bit is a logical ZERO.

Bit 11	0	Symbols are displayed unblinking.
	1	Symbols are displayed blinking at a 0.5 cps rate, 0.25 second on, 0.25 second off.
Bit 12	0	Symbols are displayed normally.
	1	Characters are written vertically as though they had been written normally and the CRT had then been rotated 90° counterclockwise (Fig. 3 shows this). Vectors and points are displayed defocussed with the width of the electron beam at least three times normal.
Bits 13 - 23		Specify the address from which the next display word shall be obtained when the branch is not effective.

The use of branch words with the contents of bits 13 - 23 equal to 0000_8, 0001_8 or 0002_8 permits the display origin to be shifted right, left, and up respectively, creating displays in the marginal areas of the CRT between the square described by the coordinate system and the round edge of the tube. The coordinate shift is equal to 1/4 of the corresponding display dimension.

DATA ENTRY FACILITIES

The display console permits a number of different types of data entry actions to be taken by the operator. These actions require the operator to use the display or the associated typewriter to compose one or more data words of 24 bits. Immediately upon the generation of a word, it is stored in the display memory and, if the action is complete, the computer is notified that a data entry has been generated. It is the responsibility of the computer program to then

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transfer the data word(s) out of the display and interpret them according to rules given below. The first 128 addresses in the display memory are reserved for the storage of data entry words before they are transferred to the computer.

Light Pencil - Raster Mode

During the presentation of a raster the light pencil is in the raster mode. In this mode it is used to identify locations on the face of the CRT. When the light pencil detects a point in the raster it generates a word coded as follows:

Bits 0, 1	00	Identify a raster mode word
Bits 2, 3		Not specified
Bits 4 - 23		Give the X and Y coordinates of the point detected by the light pencil.

Light Pencil - Symbolic Mode

At all other times the light pencil is in the symbolic mode. In this mode when a displayed item is detected by the light pencil a word is generated which is coded as follows:

Bits 0, 1	10	Identify a symbolic mode word
Bits 2 - 9		Not specified
Bits 10, 11		Identify which portion of the memory word contained the code of the detected item. Any one of one, two, three, or four sections of the word might have caused the particular display in question, and these two bits are coded to identify which character, short vector, or near point was detected.

| Bits 12 | | Not specified |
| Bits 13 - 23 | | Identify the display memory address from which the display word was taken. |

Switch Inquiries

The 22 control panel switches may be used for the generation of data entry words. Operation of the Activate pushbutton below these switches causes the generation of the inquiry and its storage in memory. The inquiry word is coded as follows:

| Bits 0, 1 | 01 | Identify a switch word |
| Bits 2 - 23 | | These bits are associated, in order, with the switches numbered 1 through 22. For each switch that is depressed when the data entry is generated the corresponding bit is set to a logical ONE, while for each switch not operated the corresponding bit is set to a logical ZERO. |

Typewriter

An electric typewriter may be associated with each display console to generate data entries for transmission to the computer via the display memory. Operation of the typewriter in the manner described in the paragraphs of this section results in the generation of a series of words the first of which is coded as follows:

| Bits 0, 1 | 11 | Identify a typewriter mode word |
| Bit 2 | 0 | Indicates a normal typewriter entry |

	1	Indicates that a message sent _to_ the typewriter has been printed.
Bits 3 - 7		Not specified
Bits 8 - 15		Contain the character code of the first symbol typed by the operator.
Bits 16 - 23		Contain the code of the second typed symbol.

Words following the first are coded in three-bit groups identifying three character or typewriter function keys operated by the typist. Coding of typed characters continues until the end of message code is received from the typewriter after which the next word is coded in one of the identifying forms given above.

If it is necessary to transfer a part of a typewriter message to the computer before it has been completed, the last meaningful character code transmitted is the partial message code (36). The next typewriter inquiry will be interpreted by the computer as completing this partial message.

Other kinds of data entries may not be generated during the loading of a typewriter message and any attempt to do so results in the Illegal Entry light being lit.

The typewriter is also used for printing data received from the computer. In this operation any portion of the display memory may be used as a buffer to hold the data from the computer until such time as the typewriter can complete printing it. Upon completion of the printing operation the console enters a typewriter mode word in its memory with the first three bits all set to a logical ONE.

The appendix shows the characters and their codes which are used in messages to and from the typewriter.

SECTION VI

FUTURE DISPLAY DEVELOPMENTS

This section outlines a number of modifications to the display console which have been suggested in order to improve its usefulness or to test the usefulness of some new display technique or logic.

RASTER MODE

The raster mode display word will be eliminated and the display logic will generate two data entry words for every light pencil action. These will be the same two words as described in the previous section, but generation of the word giving the X and Y position of the light pencil will be the display logic.

LIGHT PENCIL INHIBIT

A control word from the computer will be provided to prevent light pencil actions being taken on display data following it. Another control word will be used to re-enable the light pencil.

DISPLAY MODIFICATIONS

The display modification bits in the branch word will be located in a special control word as will the controls for offsetting the origin of the display coordinate system.

DISPLAY SUBROUTINES

It would often be useful to be able to display in a number of different locations, simultaneously or in different programs, the same display pattern much as it is now possible to display the same character in many different locations simply by calling up its code. This sort of display subroutine can be obtained provided there is some way to re-enter the main display program at

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the point it was left when the program branched to the display subroutine. If the address following an effective branch instruction is stored for use at the end of a subroutine and may be incremented automatically the necessary logic will have been implemented. Thus each time a particular display was to be generated the program would contain:

(1)   An instruction specifying the location.

(2)   A branch instruction (assumed to be effective).

(3)   An unconditional branch (not effective) to the subroutine. The address of this instruction will be stored in a fixed memory location.

(4)   The subroutine.

(5)   At the end of the subroutine a branch instruction unconditionally referring the program to the fixed address mentioned in (3), above. An automatic incrementing of the address obtained there refers the program to the instruction following the one which branched to the subroutine.

TRACKING THE LIGHT PENCIL

In some applications it is useful to be able to use the light pencil to enter graphical data into the computer. One of the methods of doing this is to make a special pattern follow the light pencil as it is moved across the display entering location data into the computer either at regular intervals or at the command of the operator.

Jonathan Mitchell
J. Mitchell

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APPENDIX

DISPLAY CONSOLE CODING

DISPLAY CODES - FIXED CHARACTERS

Fixed alphanumeric characters and punctuation marks are coded in six bits each. Forty-four of the possible six bit codes are used for these fixed characters. In addition, one is used for a blank and one for END. These codes are listed in Table 1.

Table 1

Fixed Characters

Code (octal)	Symbol	Code (octal)	Symbol	Code (octal)	Symbol
01	1	24	U	50	Q
02	2	25	V	51	R
03	3	26	W	53	(
04	4	27	X	60	+
05	5	30	Y	61	A
06	6	31	Z	62	B
07	7	33	,	63	C
10	8	40	−	64	D
11	9	41	J	65	E
12	Ø	42	K	66	F
13	=	43	L	67	G
20	blank	44	M	70	H
21	*	45	N	71	I
22	S	46	O	72	)
23	T	47	P	73	.
				77	END

TYPEWRITER CODES

All printing characters, typewriter functions (carriage return, etc.), and control actions are coded in eight bits each. For the functional codes, the first two bits are immaterial; only the last six bits are required to define the function to be performed. The printing character codes use the first bit to identify the color (red = 1 or black = 0) in which the character is printed and the second bit to identify the case (upper or lower) in which the typewriter is to be when the character is printed.

Type Element # 1

This type element permits printing the upper case alphabet, numerals, a number of special characters for punctuation and mathematical operations, and a set of Greek letters. Codes for printing in black only are shown in Table 2.

Type Element # 2

This type element permits the printing of both the upper and lower case alphabets, the numerals and punctuation, and the set of mathematical operators, as shown in Table 3.

PROGRAMMABLE CHARACTER CODING

Programmable characters are identified by 6-bit codes as are the fixed display characters. Each code identifies four addresses in memory in which are stored the description of the character.

RULES FOR CODING THE DESCRIPTIONS OF PROGRAMMABLE CHARACTERS

The description of each programmable character is stored in four 24-bit memory words. These 96 bits are treated as nineteen 5-bit groups and one extra bit. Each 5-bit group codes one 0.2-microsecond interval. Within each interval the electron beam may be on or off, and may move 0, 1, or 2 units vertically and/or horizontally. Detailed coding rules follow in Table 4.

Backspace

The first bit of the 96 is set to a logical ZERO for most characters. If set to a logical ONE, the character position advance is inhibited and the programmable character prints in the same character space as the last character.

Upshift and Downshift

The first 5-bit coding group may be, but is not necessarily, coded differently from the other groups. If it is coded 01100 then the programmable character is shifted 1/4 character height upwards; if coded 00011 it is shifted 1/4 character height downwards.

Line Segments

All 5-bit groups are coded as follows (with the exception noted just above).

Blank/Unblank

The first bit controls whether the electron beam is on or off. When it is set to a logical ZERO, the beam is off; when it is set to a logical ONE, the beam is on. Beam turn-on should be programmed to occur as soon as the beam has stabilized at the start of the line which is to be displayed. This stabilization takes one time interval without motion but the beam must not be turned off until two time intervals have elapsed, with no beam motion programmed, after the end of the line to be displayed has been reached. This restriction permits the deflection circuitry, which has a longer delay than the intensification circuitry, to catch up.

Horizontal Beam Movements

The second and third bits of each 5-bit group control the horizontal motion of the electron beam as it traces out the desired character. Each

character is written by straight lines joining points in a nine by nine array. Initially, the beam starts in the lower left hand corner of this array. It may be moved 0, 1, or 2 units in each time interval. If both second and third bits are ZERO, there is no horizontal motion; if the bits are coded 01, the beam will move one unit horizontally, and if these bits are 10, the beam will move two units horizontally. These motions are all towards the right, initially. If motion towards the left is required, these two bits may be coded 11. During that time interval, the beam will not move horizontally; but subsequent motion codes will move it left. Each time the code 11 is used, the direction of beam travel reverses. It is impossible to move outside of the nine by nine array of points except, of course, that the upshift and downshift commands have the effect of moving the whole array up or down.

Note that it is also necessary to wait one time interval at every square corner in order for it to appear square.

Vertical Beam Movements

Bits four and five encode vertical motion of the beam exactly the same manner as bits two and three code the horizontal motion. However, the vertical distance between points in the nine by nine array is normally set to 4/3 of the horizontal distance, thus giving the 4/3 height to width ratio for the characters.

Table 2

Type Element # 1 Codes

bits DL$_1$, DL$_2$, DL$_3$ / bits DL$_4$, DL$_5$, DL$_6$, DL$_7$	000	001	010	011	100	101	110	111
0000	Space		-	+	Space		—	→
0001	1	*	J	A	|	←	j	α
0010	2	S	K	B	$	Σ	k	β
0011	3	T	L	C	`	t	λ	γ
0100	4	U	M	D	′	~	Ω	δ
0101	5	V	N	E	<	Λ	ψ	ϵ
0110	6	W	O	F	>	ω	{	f
0111	7	X	P	G	↑	∇	}	τ
1000	8	Y	Q	H	↓	≡		θ
1001	9	Z	R	I	/	Δ	"	i
1010	0			)	\			]
1011	=	,	(	.	?	;	[	:
1100								
1101		LF	CR	TAB		LF	CR	TAB
1110		PM	BK			PM	BK	
1111	EOM			DEL	EOM			DEL

Notes:

LF	=	Line Feed
CR	=	Carriage Return and Line Feed
PM	=	Partial Message
BK	=	Backspace
EOM	=	End of Message or End of Transmission
DEL	=	Delete or Erase

Codes for which no symbol is shown are unassigned. The typewriter cannot transmit these codes. Transmission of these codes to the typewriter will, however, cause characters to be printed and must be avoided.

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Table 3

Type Element #2 Codes

bits DL_1, DL_2, DL_3 $\overline{\text{bits } DL_4, DL_5, DL_6, DL_7}$	000	001	010	011	100	101	110	111
0000	Space		–	+	Space		_	→
0001	1	*	j	a	|	←	J	A
0010	2	s	k	b	$	S	K	B
0011	3	t	l	c	'	T	L	C
0100	4	u	m	d	'	U	M	D
0101	5	v	n	e	<	V	N	E
0110	6	w	o	f	>	W	O	F
0111	7	x	p	g	↕	X	P	G
1000	8	y	q	h	↓	Y	Q	H
1001	9	z	r	i	/	Z	R	I
1010	0			)	\			]
1011	=	,	(	.	?	;	[	:
1100								
1101		LF	CR	TAB		LF	CR	TAB
1110		PM	BK			PM	BK	
1111	EOM			DEL	EOM			DEL

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Table 4

Programmable Characters

Code (octal)	Symbol	Addresses (octal)
52	S_1	0200-0203
54	S_2	0204-0207
55	S_3	0210-0213
56	S_4	0214-0217
57	S_5	0220-0223
20	S_4	0224-0227
32	S_7	0230-0233
34	S_8	0234-0237
35	S_9	0240-0243
36	S_{10}	0244-0247
37	S_{11}	0250-0253
14	S_{12}	0254-0257
15	S_{13}	0260-0263
16	S_{14}	0264-0267
17	S_{15}	0270-0273
74	S_{16}	0274-0277
75	S_{17}	0300-0303
76	S_{18}	0304-0307

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13. ABSTRACT

Six display consoles have been purchased for the System Design Laboratory (SDL) to facilitate rapid, accurate communications between the SDL data processing facilities and the display operators. These consoles may be connected to any computer able to control IBM 729 series magnetic tape drives. Each console contains a 2048-word magnetic core memory for storing display data which is coded in a highly effective manner. It also contains display storage in the form of a 64-frame film strip any frame of which may be presented on the display. Display generation is very rapid and is capable of showing alphanumeric and special characters, straight lines, and points. The appearance of a number of the special characters is under control of the data processor's program. The display operator is provided with switches, a light pencil, and a typewriter able to generate inquiries or statements for entry into the data processor's program.

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	ROLE	WT	ROLE	WT	ROLE	WT
Display Systems Consoles Systems Design Laboratory Display Consoles						

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